Modelling of Nearshore Wave, Current and IG-Wave Motion

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LONG TERM GOAL

The long term goal is to develop accurate and efficient models for the dynamics of Nearshore processes. The model development is aiming at making the completed models useful in operational contexts. This will include the use of data assimilation to the extent it can enhance the accuracy of forecasts.

OBJECTIVES FOR THE PROPOSED WORK

The present work will contribute to the long term goal by testing and further developing the capabilities of the SHORECIRC circulation model system. In particular, we are exploring which steps are needed to bring the SHORECIRC (SC) model on a form where it can be used on a more routine basis by other users, including Naval operations planners.

APPROACH

The project is a collaborative effort between the Center for Applied Coastal Research (CACR), University of Delaware, and The Naval Research Laboratory (NRL), Stennis Space Center, Mississippi. At the CACR, Dr. Svendsen (PI) works with Dr. Qun Zhao, postdoctoral fellow (since May 15, 1999) and a grad student. At NRL, Dr. Kaihatu (COPI) works with Dr. Todd Holland, and other members of the NRL-staff.

The teams communicate regularly by email, phone and fax and the plan is that the PI's and the relevant members of the teams will meet several times a year to discuss progress and plans. Thus Dr. Kaihatu visited CACR in July and another meeting is scheduled for Jan. 2000. The project has from the outset been divided into a number of tasks. While drawing on the full collaboration from the entire team, one of the PI's has been assigned the primary "burden of initiative" for each task.

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As mentioned, the objectives are to test and further develop the SC nearshore circulation model and make it available to particularly naval users. The tasks we are planning are related to the following three main areas:

1) Model Testing and Verifications.
2) Model Developments and Analysis
3) Application Oriented Developments

The SC model is a quasi 3D-model. This means that it solves the (unabbreviated) 2D horizontal equations in the time domain. In these equations the effects (such as the dispersive mixing, Svendsen and Putrevu, 1994) of the vertical variation of the current/infra-gravity wave particle velocities are represented by coefficients which are calculated from local analytical approximations to those vertical velocity profiles. In reverse, the forcing for those profiles is obtained from the solution of the 2D-horizontal equations. The entire flow is forced by the short wave motion through the radiation stresses, $S_{\alpha\beta}$, and mass fluxes, $Q_{w\alpha}$, generated by those waves. A short wave model, called a wave driver, is used to provide information about this short wave forcing. This model has been developed over the past 6-8 years and is approaching a level where it can be used by a wide variety of users.

WORK COMPLETED

We have is nearly completed work on development of a reference version, a manual, and bench mark tests for the SC-model. This has included a serious overhaul of the computer code to remove older, now abundant model components, fine tune details of input and output and creating a test or bench-mark test that can help new users establishing the model on their computer system. It has also involved updating and testing the model to include the results of the work for generalized dispersion reported in Putrevu and Svendsen (1999). Finally we have significantly expanded the manual, which we have sent to some selected researchers for comments, will send to others in the near future, and expect to send out as a Center for Applied Coastal Research (CACR) research report.

During the testing of the model it became clear that in particular the moving shoreline boundary condition was fragile and needed to be improved. An alternative used in the past has been to place a vertical wall at very small depth (one cm or so) at the shoreline and earlier computations have indicated this remedy only affects the most nearshore parts of the flow. However, model computations performed under a related project (Sea Grant) with the formation of rip currents through channels in longshore bars also showed that even for these flows, which were not expected to seriously depend on the shoreline details, the flow in the trough behind the bars was somewhat influenced by the shoreline condition, probably due to interaction with the bars. We are therefore working on improving the shoreline condition by using a flexible grid and decreasing the grid size in the region closest to the shore to improve resolution there. This improvement is presently being tested.

We have begun steps toward validating the SC model against field data from both Duck94 and SandyDuck experiments. Data from both experiments have been obtained courtesy of Dr. Steve Elgar of Woods Hole Oceanographic Institution. Both data sets consist of mean quantities (17 minute averages) of wave and current data for both forcing and validation. Bathymetric data is also included.

We will attempt model validation with these mean quantities first, and then see if more detailed information is required. We will soon undertake comparisons to wave-forced flows from the finite-element ADCIRC model (Luettich et al. 1992). The ADCIRC model is presently being run by the

Naval Oceanographic Office (NAVO) for tidal simulation. This comparison will offer some estimate of the limitations of shelf-scale models to simulate small scale flows.

Data assimilation is also a part of the project. Under another project (Dynamically Constrained Nowcasting of Near Coastal Waves and Bathymetry, 6.2 NRL Core) we have begun using parameter estimation techniques to glean bathymetric information from the free surface imagery. These techniques consist primarily of Levenberg-Marquardt iteration, in which a parameter (in this case, the bathymetry) is varied until misfit between data and model is minimized. These kinds of techniques would be applied to the SC model to ascertain the optimum parameters (friction coefficients, etc.) for model application. An example of this for tidal models has been done by Panchang and O'Brien (1988).

Conversion of the SC model to take advantage of parallel platforms is presently being evaluated. A graphical user interface (GUI) will be used in conjunction with the model. In anticipation of the model's eventual use in operational centers, the SMS GUI system will be evaluated for model use. This system has no proprietary software associated with it, in accordance with operational model guidelines. It is also highly developed and is an excellent candidate system for the SC model.

RESULTS

As a result of the changes made to the code, the model is today close to being a full 3D rather than a quasi-3D model. This means that the main effects of the horizontal variations of the current profiles are included in the dispersive mixing terms as the full set of equations dictate. Traditionally, nearshore currents have been regarded as slowly varying in the horizontal plane, though it has always been anticipated that there could be exceptions from this rule such as the flow near the roots of rip currents. However, as we gained experience with rip currents both through measurements and model simulations it became clear that rapid variations in the horizontal direction occur everywhere both outside the surf zone and even behind the bars due to the extensive formation of large scale eddies.

As an example, Fig. 1 shows an excerpt of a computation with the SC model for a rip current. The six panels show the flow pattern at six different times (marked in seconds on each panel). They illustrate the highly unsteady nature of the flow (even though the short wave forcing is steady) and the formation of large scale vortices that are an integral part of the rip current. Laboratory measurements indicate that these currents also vary over depth and in the related Sea Grant project we are working on testing if the model can represent these variations.

Furthermore, the same extensive generation of large scale vortices has been observed as the ultimate development of shear waves, which are instabilities of ordinary longshore currents. This is also in accordance with field observations of velocities that generally show time variations that can be attributed to such vortices. Hence, we are facing the growing realization that nearshore flows are highly vortical, unsteady, and with relatively strong horizontal variations even over short distances. The currents often vary strongly over depth both in magnitude and direction, and our models need to reflect these realities.

IMPACT/APPLICATION

It is expected that the work proposed here will increase our understanding of how nearshore circulation and wave motion can be modelled. The specific tasks undertaken will not solve all problems, but it is
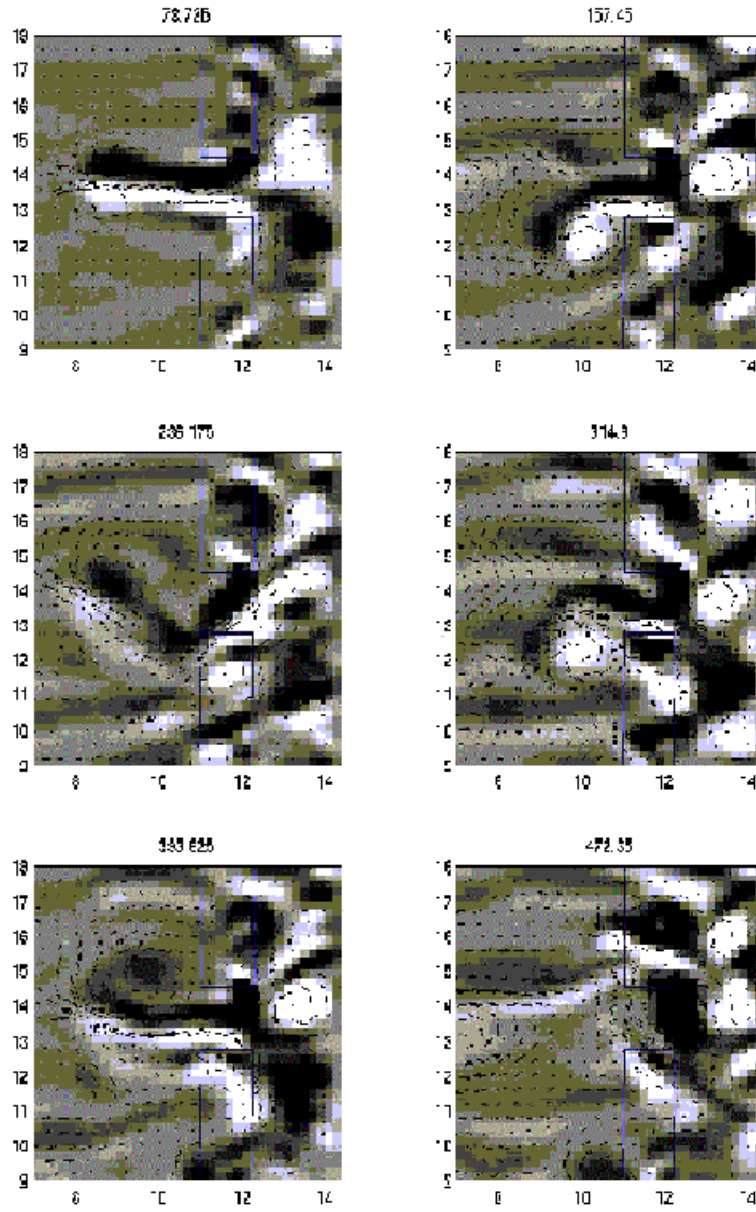
Fig. 1: Six snapshots of the velocity field (arrows) and vorticity (gray-scale) of the flow in a rip current as computed using the SHORECIRC model (excerpt from larger computational domain). The rip is generated by incoming waves in the presence of a channel in the middle of the longshore bar shown underneath the velocity field. The times are shown above each panel in seconds (laboratory scale which is approximately 1/10 of typical real scale). The flow is highly unsteady and shows the strong development of large scale vortices.

believed that they are important steps toward the long-term goal of a complete and efficient modelling of nearshore circulation. This would particularly pertain to the goal of developing the comprehensive SHORECIRC model for integration into existing Naval modeling schemes as well as furthering the transition of the model to the operational Navy. It would also greatly help the work toward developing a tool that can assist in the analysis and enhancement of the data collected during field experiments.

TRANSITIONS

In addition to the two PI's working on the SC model, it has been passed on to my former graduate students Dr. Ap Van Dongeren, Delft Hydraulics, The Netherlands, Dr. Francisco Sancho, LNEC, Lisbon, Portugal, and Dr. Jane McKee Smith, WES, Vicksburg. In addition, Dr. Tuba Özkan-Haller and Dr. Dan Conley have asked for the model and will get it as soon as the testing of the reference version an the manual has been completed. After these people have had the chance to review and test the model and comment on it, it is planned to make it available to the scientific and engineering community via the Internet while the other tasks of the present project are being pursued. The model will further be developed under the NOPP project "Development and verification of a comprehensive community model for physical processes in the nearshore ocean." The SC model is also a featured model in the proposed "Wave Induced Nerashore Circulation Environment Simulation (WINCES)" Project (NRL 6.2 CORE); this is proposed for FY01; PI's: Kaihatu and Holland.

RELATED PROJECTS

"The generation of Rip currents and circulation around coastal structures." PI: I.A. Svendsen
    (Sponsor: NOAA, Sea Grant).
"Surf and surf zone hydrodynamics." PI: Peregrine, CoPI: Svendsen (Sponsor: ONR NICOP).
"Hydrodynamics of the nearshore zone." PI's: Dalrymple, Kirby, Svendsen (Sponsor: ONR).
"Development and verification of a comprehensive community model for physical processes in the
    nearshore ocean." PI's: Kirby, Svendsen, (at UD, and others outside UD), (Sponsor: NOPP).
"Dynamically Constrained Nowcasting of Near Coastal Waves and Bathymetry." PI: James Kaihatu
    (Sponsor: NRL 6.2 Core).
"BAYS". PI: Cheryl Ann Blain (Sponsor: NRL 6.2 Core).

REFERENCES

Luettich, R.A., J.J. Westerink, and N.W. Scheffner. ADCIRC: An Advanced Three-Dimensional Circulation Model for Shelves, Coasts and Estuaries. Report 1: Theory and Methodology of ADCIRC-2DDI and ADCIRC-3DL, *Technical Report DRP-92-6*, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS 137 pp., 1992.

Panchang, V.G., and J.J. O'Brien. On the determination of hydraulic model parameters using the adjoint state formulation. In *Marine Modeling Systems*, ed. A.M. Davies, 5-18, Boca Raton: CRC Press, 1988.

Putrevu U. and I.A. Svendsen (1999). Shear Dispersion of Momentum in the Nearshore, *European Journal of Mechanics, B/ Fluids*, **18**, 3, 409 -428.

Svendsen, I.A. and U. Putrevu (1994)

PUBLICATIONS

Putrevu U. and I.A. Svendsen (1999). Shear Dispersion of Momentum in the Nearshore. *European Journal of Mechanics, B/ Fluids*, **18**, 3, 409-428.

Sancho, F.E., I.A. Svendsen, & U. Putrevu (1999). The effect of on nearshore circulation of weak longshore topographic variations. Submitted for publication.

Svendsen, I.A. and K.A. Haas (1999). Interaction of undertow and rip currents. *Proc. 5th Int. Conf. Coastal and Port Engrg. Developing Countries*, ASCE. 218-229.

Sancho, F. , C. J. Fortes, J. L. Fernandes and I. A. Svendsen (1999). On the wave field and wave-induced currents around a detached breakwater", to appear in ASCE *Proc. Coastal Structures Conf*, Santander.

Van Dongeren, A.R., I.A. Svendsen (1999). Nonlinear and quasi 3-D effects in leaky infragravity waves. Submitted for publication.